US Army Corps
of Engineers
North Central Division

GREAT LAKES LEVELS

Update Letter No. 91 February 1, 1993

Winter Ice Monitoring on the Great Lakes - St. Lawrence System

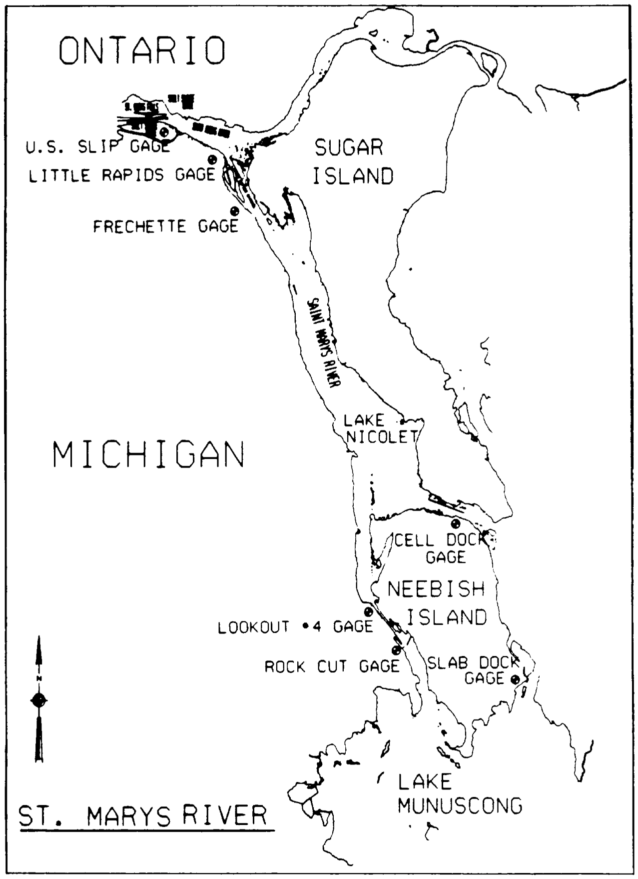
Winter in the Great Lakes generally brings lots of ice and snow. This season has been no exception. In fact, the trend towards above average precipitation, seen in the last half of 1992, continued into January 1993. This has resulted in an escalation of higher levels in the lower Lakes region. As such, it is important to publish this article with an update of present conditions and an outlook for the Spring of 1993. Lakes Michigan-Huron, St. Clair, and Erie have essentially missed their usual seasonal decline which has caused levels to digress appreciably from their long-term averages. The January monthly mean lake levels, compared to the January long-term averages (1900-1992), show Lake Michigan-Huron is 7 inches above average; Lake St. Clair is 24 inches above average; and Lake Erie is 26 inches above average. Lake Ontario, as the recipient of all the waters from the upstream lakes, has also trended upward in the last 6 months and is now 19 inches above average. Based on the above information and in anticipation of the normal spring rise, shoreline residents of Lakes St. Clair, Erie, and Ontario are alerted to possible extreme lake levels. Water level setups and wave actions caused by storm conditions can often be very serious and may require residents to protect their property. Should conditions worsen, the Corps of Engineers will provide further information and advice to shoreline residents through these Update Letters.

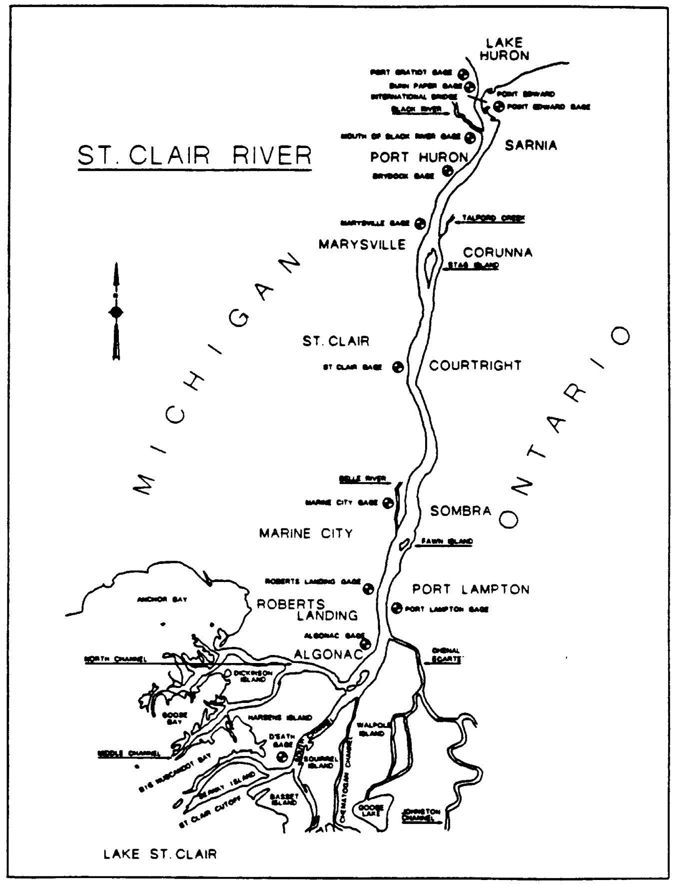
Two important arteries of commerce in the Great Lakes Region are its highways and its waterways. During the winters, the highways are salted and plowed, but the waterways are generally left to nature. Those rivers not outfitted with ice booms occasionally suffer ice jams and shoreline flooding. The focus of this article is on the Winter Ice Management Program, which is an international, multi-agency effort in the Great Lakes.

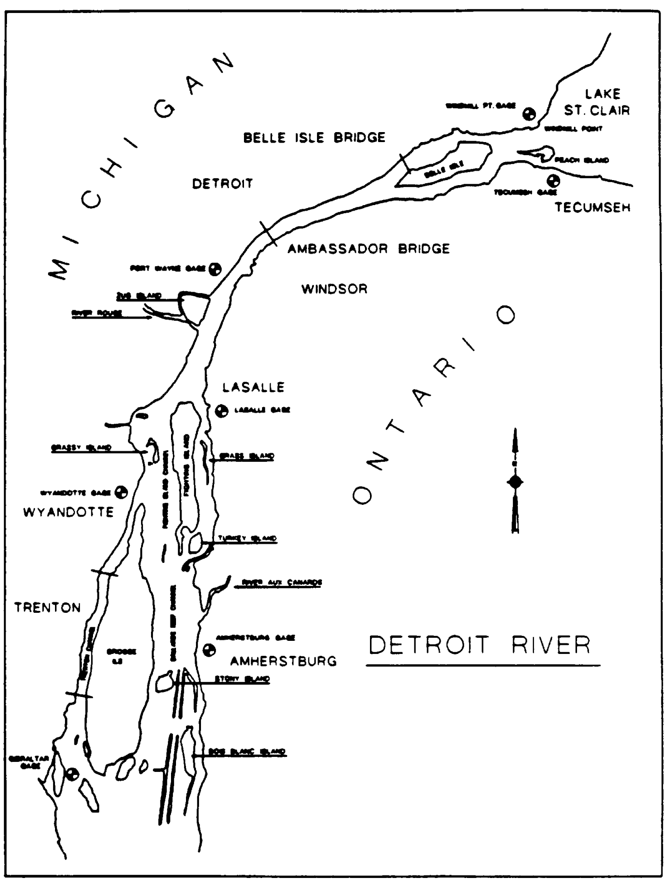
Each winter, the U.S. Army Corps of Engineers (USACE), Detroit District, initiates an ice monitoring program on the St. Marys, St. Clair, and Detroit Rivers and compares its findings with the U.S. and Canadian Coast Guards and other agencies. On the Niagara River, the International Niagara Board of Control (INBC), represented by the Buffalo District USACE, Environment Canada, Ontario Hydro, and New York Power Authority, conducts a program to gather data on water temperatures and ice conditions on the east end of Lake Erie and in the Niagara River. This information assists the INBC in deciding when to install and remove an ice boom located at the head of the Niagara River.

The Winter Ice Management Program for the St. Marys, St. Clair, and Detroit Rivers is intended to detect potential flood situations and their locations, to provide the methodology for mitigating conditions that could create critical flood levels, and to direct the most efficient and beneficial course of action to relieve flooding that does occur. The program's principal concerns are to protect the health and the well-being of residents and property owners adjacent to these waterways.

The monitoring plans consist of daily observations of water level, ice, and weather conditions for the St. Marys, St. Clair, and Detroit Rivers. This is accomplished, in part, using a water level gage network consisting of seven, eight, and four gages for each of the rivers, respectively. (See Figure 1.) All of the gages are equipped







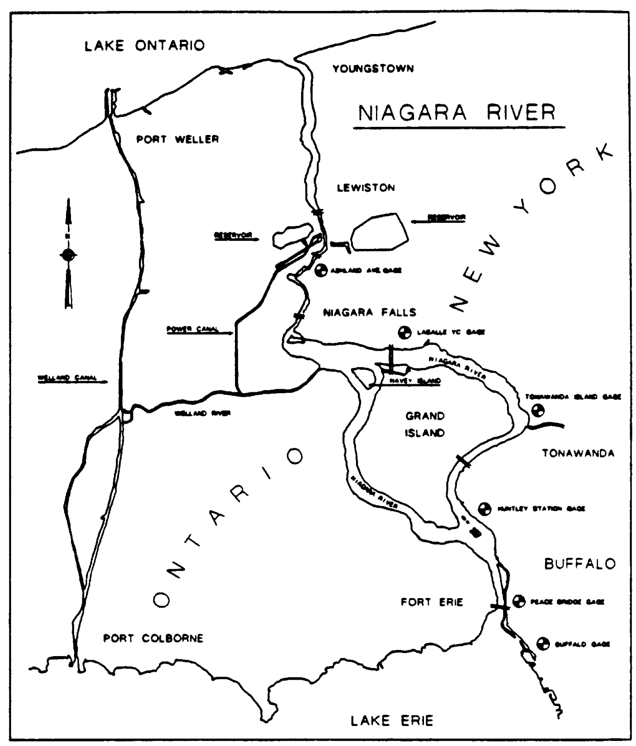


Figure 1. Gage locations on the connecting channels

St. Clair River

Hydrograph of a Typical Ice Jam

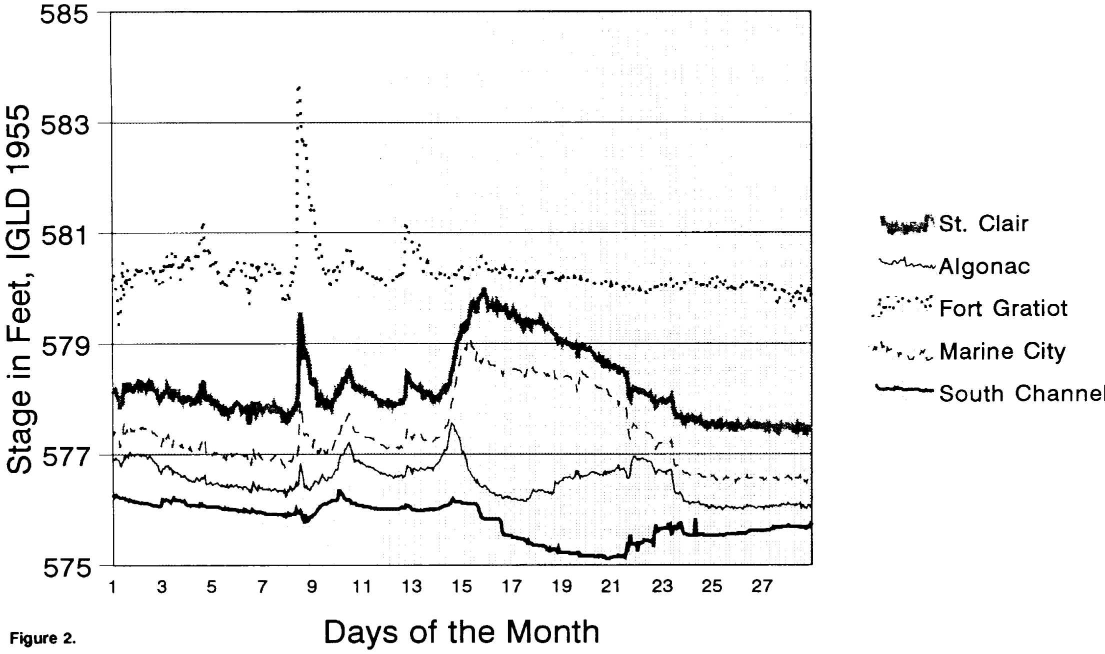


Figure 2.

Figure 3. Aerial observation of ice on the St. Clair River

with Data Collection Platforms (DCPs) which can be accessed via telephone for instantaneous readings, as well as transmitting hourly water level readings, at four hour intervals, via satellite.

Water level readings are gathered and stored in databases. From these databases, color coded hydrographs of each river are generated to show the most recent stages at each gage site. Reviews of the hydrographs and other information on river conditions, such as the amount of ice (flowing or stationary), wind direction, and air temperature, are made by USACE employees, as the situation warrants. (See Figure 2.) Hydrographs are used for real-time graphic detection of ice jams along the river. When a hydrograph depicts an abnormality in water levels, such as a continued rise of an upstream gage and a corresponding fall in the adjacent downstream gage, the U.S. Coast Guard (USCG) will be called to obtain additional information on river and wind conditions.

On-the-spot observations are used to locate, assess and document adverse ice conditions. Depending on visibility and weather conditions, personnel may be dispatched via an aircraft to obtain aerial observations and/or video or still photography. (See Figure 3.) Contact with the USCG is maintained for up-to-date information on ice and wind conditions.

Flood Stage Actions

Whenever the St. Marys, St. Clair, or Detroit Rivers reach the minor flood stage, a determination of the possible cause (wind, ice shift, etc.) is made. If water levels continue to rise, USACE notifies the USCG and counterpart Canadian agencies. Possible action by the USACE may require collection of additional field data such as the measurement of ice thickness in critical reaches of the river. For instance, on the St. Marys River at Sault Ste. Marie, the amount of water flowing through the regulatory structures is closely monitored by the USACE, while navigation is observed in conjunction with the USCG.

The USCG may be asked to provide icebreaker assistance to aid in mitigating potential flooding caused by ice retardation and blockages at any flood stage, depending upon local conditions.

The National Weather Service (NWS) will be informed of flood stages by the appropriate USACE representative, so flood warnings can be issued to the public. The NWS is responsible for providing operational river forecasts and any flood watches or warnings to the public. The proper Canadian authorities are made aware of the potential flood conditions.

At the alert flood stage, if conditions warrant, the USCG will be requested to limit navigation in the river.

Under present operational procedures, the winter outflow from Lake Superior is limited by Regulation Plan 1977-A to fall within a range of 55,000 cubic feet per second, cfs (minimum), to 85,000 cfs (maximum), depending on water levels of Lakes Superior, Michigan-Huron, and Soo Harbor. Generally, once the gate opening in the Compensating Works is established in December, it remains constant throughout the winter (Dec-Apr). Any flow changes that may be required by the International Joint Commission during the winter will be effected through the hydroelectric powerhouses.

If the water level at Soo Harbor reaches the major flood stage, and a reduction in Lake Superior outflow is necessary, gates in the Compensating Works are closed to the minimum allowable. If attempts to close gates in the Compensating Works are impractical due to excessive ice build-up, the U.S. and Canadian International Joint Commission (IJC) On-Site International Lake Superior Board of Control (ILSBC) Representatives direct the shut-down of all flow (if any) through the U.S. Locks, reduction of flow through the Edison Soo Electric Company and the U.S. Government powerhouses; and request the Canadian ILSBC On-Site Representative to reduce flow through the Great Lakes Power Limited powerhouse.

To help stabilize the ice cover in Soo Harbor, to moderate ice problems in the cut, and to aid winter navigation, an ice boom with an opening for navigation was placed at the head of Little Rapids Cut for the winter of 1975-1976. Because of its proven effectiveness during that winter, the boom continued to be deployed each winter during the Great Lakes-St. Lawrence Seaway Navigation Season Extension Program. Although boom placement was scheduled to be discontinued following the winter of 1978-1979, a decision was made to continue its deployment indefinitely.

In general, the ice boom

proved to be valuable in stabilizing the ice cover in Soo Harbor, reducing the extent of ice accumulation in Little Rapids Cut and reducing the amount of ice in the Sugar Island ferry crossing. By lessening the possibility of ice jams in the cut, the ice boom reduced the likelihood of emergency cutbacks in outflow from Lake Superior, which would result in power generation losses at the hydropower plants. By curtailing the adverse affects of natural ice conditions on the Sugar Island ferry, the ice boom has contributed to more reliable winter transportation between Sugar Island and the mainland.

International Niagara Board of Control Winter Monitoring Program

In 1964, with the IJC's approval, the Power Entities, Ontario Hydro, and the New York Power Authority installed a floating timber ice boom in Lake Erie, near the head of the Niagara River. The boom has been installed early in the winter and removed in the spring each year, since its main purpose is to reduce the frequency and duration of heavy ice runs into the Niagara River which may lead to ice jams.

As directed by the IJC, installation of the boom's floating sections starts when the Lake Erie water temperature, as measured at the Buffalo, New York water intake, reaches 4 degrees Celsius (C), 39 degrees Fahrenheit (F). This past winter, installation of the Lake Erie - Niagara River Ice Boom commenced on 20 December and was completed on 27 December.

The New York Power Authority has also entered into a recent contract for the "Assessment of Ice Boom Technology for Application to the Upper Niagara River." The study will assess potential performance of the ice boom based on new developments in ice boom technology which have been developed in the last 30 years.

The Board's 1992-1993 ice monitoring program will primarily consist of :

1. Fixed wing and helicopter flights over the eastern end of Lake Erie and the Niagara River to gather information on the extent, quantity and quality of ice. These data will be placed on the Geographic Information System (GIS), enhancing the quality of the ice maps. Data gathered during the reconnaissance flights will include area of ice, percentage of ice coverage, characteristics of the ice, shipping conditions at Port Colborne, Ontario, and Buffalo, New York and other information.

2. The use of meteorological data, obtained from NWS, in mathematical models to predict the commencement of the seasonal rise in water temperature and forecast the date of last ice in eastern Lake Erie.

In addition to these observations, the Board relies upon information such as satellite imagery and composite ice charts received from other agencies.

St. Clair and Niagara River Ice Models

Another aspect of the ice monitoring program is an ice model for the St. Clair River developed for the Detroit District, USACE, by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). The model provides forecasts of water temperature, ice formation, extent of ice cover, ice cover thickness, duration of ice cover, along with water levels and discharge. The model utilizes data from two temperature probes, one at the upstream boundary between Lake Huron and the St. Clair River, at the Dunn Paper Company, in Port Huron, Michigan; and one at the downstream boundary between the foot of the river and the delta region at Algonac, Michigan. In addition, an ice arch formation prediction can be generated using the five day moving average of the daily mean air temperature methodology.

The Buffalo District, USACE, also utilizes an ice forecasting model, developed by CRREL to predict ice freeze-up and its severity along the International Section of the St. Lawrence River.

The New York Power Authority contracted the construction of a physical model to simulate the movement of ice through the Niagara River's Chippawa-Grass Island Pool located just above Niagara Falls. The 200 x 70 foot model, completed in June 1992, will reproduce past ice jams and test alternatives for improving the ice transport capacity of the pool area.

The aforementioned mathematical and physical models may help predict ice jams and assist in their removal. In the Great Lakes area, the period of freezing temperatures is generally not long enough to cause a lake-wide ice sheet to form. Ice formation and melting sometimes go on simultaneously at different locations. The effects of winds, currents, and upwelling cause rapid changes on the ice cover, making predictions of ice thickness and distribution difficult. As such, the formation of ice jams can be uncertain and erratic, as was the case in the record-breaking April 1984 ice jam on the St. Clair River.

April 1984 St. Clair River Ice Jam

Historically, during the winter, various quantities of floe ice from Lake Huron enter the St. Clair River, generally under the influence of northerly winds. The swift currents in the upper river carry the floes downstream until meeting the resistance of the solid ice cover of Lake St. Clair. The broken ice pieces tend to compress into a jagged ice cover that backs upstream as more ice enters the system. During a normal winter, the ice cover may extend from the mouth of the river upstream 5 to 10 miles. The main factor which influences the amount of ice entering the river is the stability of an ice bridge (natural ice arch) that forms in lower Lake Huron at the head of the St. Clair River. The ice bridge may be destroyed many times during a winter, but reconsolidates itself. It also causes lake ice to consolidate and freeze together into a solid, stable sheet bridging the river entrance from the U.S. to Canada. This condition may last through the winter or may be disrupted by southerly winds which tend to break up an ice cover. When the wind shifts northerly, the broken ice is pushed into the river. In extreme cases, this process continues until an ice jam occurs which may severely reduce the flow in the river.

The 1983-84 winter season was characterized by severe cold spells near the end of December and the first half of January, producing a large ice cover on Lake Huron. This situation was followed by a very warm February and a cold March, producing some ice thawing and refreezing, respectively. April temperatures were normal with a large volume of ice remaining in southern Lake Huron.

On April 1, 1984, based upon guidance from the winter monitoring program and the fact that no ice existed in the St. Clair River, Lake St. Clair, or the Detroit River, real-time water level monitoring ceased. On April 5,1984, intense northerly winds caused a great deal of ice to float downstream in the vicinity of Marine City, resulting in a rise of water levels at the St. Clair gage. On the morning of April 6, gage readings indicated that the St. Clair River at Marine City was very near flood stage, while the level at Algonac had dropped sharply from its previous days reading, indicating that an overnight ice jam may have developed. Later that afternoon, NWS issued a flood warning, and the next day the ice jam moved upstream of Marine City, causing levels at the St. Clair State Police Post gage to rise sharply. Flooding was also reported at other points along the river.

The USCG was called in to break ice in the navigation channel and in the St. Clair River. The USCG recommended that vessels travel in the river only in the daylight hours, and with icebreaker assistance. By the morning of the 16th, the U.S. and Canadian Coast Guards issued a notice that, due to the severity of the ice jam, all vessels were restricted from entering the river. Fifteen miles of ice cover remained in Lake Huron, north of Port Huron, and ice was continuing to spill into the St. Clair River. On the morning of April 20th, the NWS reported a slight easing of ice conditions.

On April 30th, both Coast Guards indicted that all vessels were able to navigate the river without icebreaker assistance and that all Coast Guard vessels were being recalled. It was also reported that the ice in the St. Clair River was rapidly moving south with the current. Based on this information and a review of the river levels, river ice monitoring under the ice jam monitoring program finally ceased.

The April 1984 St. Clair River flow averaged 130,000 cfs, or approximately 90,000 cfs below the flow expected under ice-free conditions. The Detroit River flow that month was also about 90,000 cfs less than normal for the same period. Since no ice existed in the Detroit River during April, the decrease in the flow that month was entirely the effect of the reduced inflow of water from Lake St. Clair due to the ice jam on the St. Clair River.

After the April 1984 ice jam on the St. Clair River, it was determined that April 1 was an inappropriate date for termination of ice monitoring. Subsequently, the ice monitoring program was revised, and is currently reviewed on an annual basis.

Previous Update Letters With Related Topics

Update Letter No. 68, March 4, 1991, St. Marys River Ice Boom;

Update Letter No. 65, December 4, 1990, Ice Booms are Vital to Winter Operations on the Great Lakes;

Update Letter No. 20, March 4, 1987, mentions the St. Clair River Ice Jam which occurred in February 1987.

Russell L. Fuhrman

Russell L. Fuhrman
Brigadier General, USA
Commanding

Great Lakes Basin Hydrology

The precipitation, water supplies, and outflows for the lakes are provided in Table 1. Precipitation data include the provisional values for the past month and the year-to-date and long-term averages. The provisional and long-term average water supplies and outflows are also shown.

Table 1
Great Lakes Hydrology[1]

PRECIPITATION (INCHES)								
BASIN	JANUARY				YEAR-TO-DATE			
	1993*	AVG.**	DIFF.	% OF AVG.	1993*	AVG.**	DIFF.	% OF AVG.
Superior	1.8	2.0	-0.2	90	1.8	2.0	-0.2	90
Michigan-Huron	2.7	2.1	0.6	129	2.7	2.1	0.6	129
Erie	4.0	2.4	1.6	167	4.0	2.4	1.6	167
Ontario	3.6	2.6	1.0	138	3.6	2.6	1.0	138
Great Lakes	2.7	2.2	0.5	123	2.7	2.2	0.5	123

LAKE	JANUARY WATER SUPPLIES***		JANUARY OUTFLOW[3]	
	1993[2]	AVG.[4]	1993[2]	AVG.[4]
Superior	11,000	-14,000***	80,000	69,000
Michigan-Huron	126,000	53,000	169,000[5]	158,000
Erie	99,000	25,000	238,000[5]	192,000
Ontario	78,000	32,000	247,000	221,000

*Estimated **1900-91 Average ***Negative water supply denotes evaporation from lake exceeded runoff from local basin.

[1]Values (excluding averages) are based on preliminary computations.
[2]Cubic Feet Per Second (cfs) [3]Does not include diversions [4]1900-89 Average (cfs)
[5]Reflects effects of ice/weed retardation in the connecting channels.

For Great Lakes basin technical assistance or information, please contact one of the following Corps of Engineers District Offices:

For NY, PA, and OH:
COL John W. Morris
Cdr, Buffalo District
U.S. Army Corps
of Engineers
1776 Niagara Street
Buffalo, NY 14207-3199
(716) 879-4200

For IL and IN:
LTC David M. Reed
Cdr, Chicago District
U.S. Army Corps
of Engineers
River Center Bldg (6th Flr)
111 North Canal Street
Chicago, Il 60606-7206
(312) 353-6400

For MI, MN, and WI:
COL Brian J. Ohlinger
Cdr, Detroit District
U.S. Army Corps
of Engineers
P.O. Box 1027
Detroit, MI 48231-1027
(313) 226-6440 or 6441